Lie Detection Using Acceleration Plethysmography Signal

Khairul Azami Sidek, Nur Amirah Shariff, Md Nasibul Alam, Nuradilah Hashim and Ahmad Fadzil Ismail
Department of Electrical and Computer Engineering,
Faculty of Engineering, International Islamic University Malaysia,
P.O. Box 10, Jalan Gombak, 50728 Kuala Lumpur.
azami@iium.edu.my

***Abstract*—Crime records are reported to show an increasing pattern over the years and it is heart breaking since crimes cases will affect a lot of people especially the victims since they have to face severe loss. Interrogations in crime cases are fundamental since this is the element that will determine the status of the crime and the perpetrator. In order to prevent from any deceptions by the criminals, lie detector might be an invention that will be a great help to separate truth and lies. Due to this, the study proposed a lie detector technique using APG signal. APG signal is the second derivative of PPG that can be obtained by placing detector at the fingertip. Literature reviews on related topics were conducted to gather more information regarding deception detection. In order to realise our objective, the proposed methodology is constructed with data collection as the first step. The data were collected form 10 subjects in form of PPG signals. The next step is signal transformation where PPG signals are converted into APG waveforms and the transformed signals will then undergo pre-processing to eliminate noise. Both techniques use MATLAB as the platform to obtain the output. The following step is feature extraction where the filtered signals undergo segmentation to point out the important information to be used in the next stage. The last step is classification where the extracted data is analysed to perform a conclusion whether the subject is lying or telling the truth. This process involves analysing 3 characteristics of the signals which are the Peak to Peak Interval (PPI), Peak Height Difference and Cardioid graph. Results from the experimentation indicates that PPI is not suitable as a mean to differentiate deception and truth as the difference between these two signals are trivial. Peak Height Difference and Cardioid graph are more suitable to detect lies in both PPG and APG signals since there are significant different in PPG and APG waves when subject are telling lies as compared to telling the truth.**

***Index Terms*—APG Signals; Cardioid; Lie Detection; Peak Height Difference; PPG Signals; PPI.**

I. INTRODUCTION

Crimes cases will affect a lot of people especially the victims since they have to face severe loss. Interrogations in crime cases are fundamental since this is the element that will determine the status of the crime and the perpetrator. During this process, being able to differentiate lying and telling the truth will determine whether the subject is guilty or not. Traditional methods of detecting lies include observation on facial expression and emotion but these techniques have their own limitation as it can be faked by the respondent. Due to this, signals which are coming from the inner part of body or biosignals are being introduced in lie detection since a relationship between detecting lies and natural body signals have been discovered. These measurements are more accurate because it represents a true reaction of a person. Biosignals refer to signals that are recorded from the human body. There are two types of biosignal which are electrical and non-electrical waveforms. Photoplethysmography (PPG) are one of the examples of electrical biosignals. Recently, acceleration plethysmography (APG) was introduced as an alternative to PPG. APG indicates a signal that applies the second derivative of the waveform of the digital PPG. The waveform patterns of PPG and APG are shown as in Figure 1.

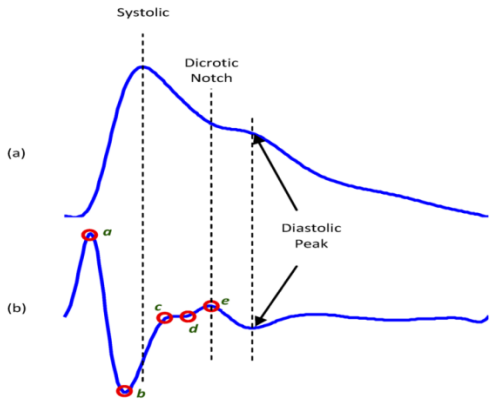

Figure 1:(a) PPG waveform and (b) APG waveform [1]

APG signal are used in many medical fields and clinical applications since heart rate (HR) and heart rate variability (HRV) can be calculated using APG. APG is also an optical procedure that has been developed for experimental use in vascular diseases. It is considered a promising tool that may replace some of the current traditional cardiovascular diagnostic tools. The possibility of using APG for lie detection will be investigated in this study as a complement for currently available deception techniques. Therefore, we will propose a lie detection technique using APG signal. A correlation between APG signal and lie detection will be discussed in this study.

II. LITERATURE REVIEW

A study by Oweyjan et al. in [2] discovered a lie detection system using facial micro expression using image processing techniques where it detects a micro-ecpression when the subjects is lying. Singh et al. in [3] suggested a method for lie detection using image processing techniques based on blink rate. From this study, it is found out that the blink rate for lying participants are higher and far from the target blink rate as compared to the subjects who are telling the truth with as

high as 30 blinks per minute. Another research done by Lange et al. in [4] revealed an approach of Interrogative Polygraphy using precise time-localized Enterprise resource planning (ERP) and frequency localized (EEG) brain signals. This study measured subject's stress level and relates it with lie detection.

Noje and Malutan in [5] suggested a head movement analysis in lie detection and obtained a result that the head movement between lying and telling the truth participants varies. Zhu et al. in [6] recommended a forehead thermal signature extraction in lie detection approach. This research concludes that the forehead temperature of almost all of the subjects appears to rise when telling lies. A study by Proudfood et al. in [7] disclosed an investigation of pupil diameter variation in automated deception detection. The outcomes show that pupil diameter varies over the period of deception where and the pupil diameter decrease rapidly. Participant who lied had significantly higher intercept for pupil diameter ($p<0.05$mm) relative to innocent participant.

There are many researches done on lie detection and anxiety detection using various physiological. However, little has been said on lie detection using APG signal. This method is a new field which is less explored and comparatively still not researched widely. Therefore, in this study, the effectiveness and correlation between lie detector techniques with APG signals will be investigated and determined whether the proposed method would improve and enhance the accuracy of lie detection system.

III. METHODOLOGY

Methodology for the study of lie detection using APG signal and the logic behind the selection of the techniques used are explained in this section and the flow of the study's methodology is represented by five methods as shown in Figure 2. Data collection is the initial process followed by signal transformation. The third process is pre-processing where filtering is used which then will be trailed by feature extraction. The final process of the study is the classification process.

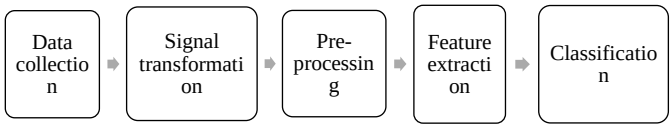

Figure 2: Proposed methodology

A. Data Collection

Data collection is done by having 10 volunteers to undergo an experiment in order to obtain their PPG readings. They were asked steal a purse that was left unattended and try to convince the examiner that they did not steal anything by answering the set of questions given. While the questioning process takes place, the PPG reading of the subjects is taken using Easy Pulse and Arduino Uno which then will be read using Cool Term software. Figure 3 shows the device used to collect the PPG signals. The data collected will undergo several more processes to find the correlation of signals when the subject is lying and when they are in a normal condition.

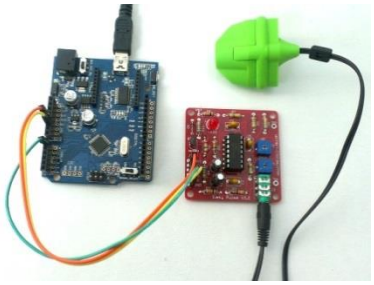

Figure 3: Arduino Uno and Easy Pulse

B. Signal Tranformation

In signal transformation, MATLAB is used as the platform to convert PPG to APG waveforms. Considering that APG is the second derivative of PPG signal, the derivations of the PPG signals will be attained through the diff() command in MATLAB. The output which is APG waveforms will show a distinct or clearer waveform as compared to PPG. This value is then passed to the next process which is the pre-processing stage.

C. Pre-processing

The waveforms obtained from the signal transformation have to undergo pre-processing before further procedure which is feature extraction can be conducted as the waveform contains noise. In order to have useful data and accurate information the pre-processing which is filtering stage is carried out. MATLAB is used to filter out the noise from the waveform with the [B,A]=butter(2,0.1,'low') command. MATLAB offers various filtering processes and in this study Butterworth filter is used as ir have a good all-around performance. Butterworth also have a pulse response which is better than Chebyshev and a rate of attenuation that is better than Bessel.

D. Feature Extraction

Feature extraction is a vital step in the methodology since this process discriminate important and useful data from excess information to be recorded for better interpretation. This procedure is essential when the input data is suspected to be redundant thus resulting it to be difficult to be processed since it is too large. Since APG signal is the second derivative of PPG signal, both waveforms consist of systolic and diastolic parts. For this study, data will be extracted from point a up to point c of the APG signal since this range consist of many important information that can be used to determine condition of the respondent. The method used to obtain the feature extraction is by finding peaks or point a of the APG signal using MATLAB function with the findpeaks() command and then mapping together a few signals to get the segmented APG signals.

E. Classification

After an observation is made from feature extraction, the data will then undergo classification procedure to determine whether an individual is lying or telling the truth. Classification is also an occurrence of supervised learning where the study of pattern recognition and computational theory is taken place. For this study, 3 classification methods will be used to identify the categories of the signal based on the feature extracted of APG signal. The method used to classify whether the respondent is lying or not includes Peak to Peak Interval (PPI), Peak Height Difference and Cardioid graph.

IV. EXPERIMENTATION AND RESULTS

Ten sets of PPG signals from ten different individuals were collected with Easy Pulse will be processed using MATLAB to obtain the final output which is PPG and APG signal waves with distinct feature extraction and classification for lie detection. After transformation of PPG signals into filtered APG signals, the segmented signals of normal and lie PPG and APG are than mapped together and compared. From the tabulated result of feature extraction, we can observe the difference between the signals when the subject is lying and when they are in normal condition. The results of the mapped signals and cardioid graphs for three subjects in both normal and lie condition is presented in Figures 4, 5, 6 with subject 1, 6 and 9 respectively.

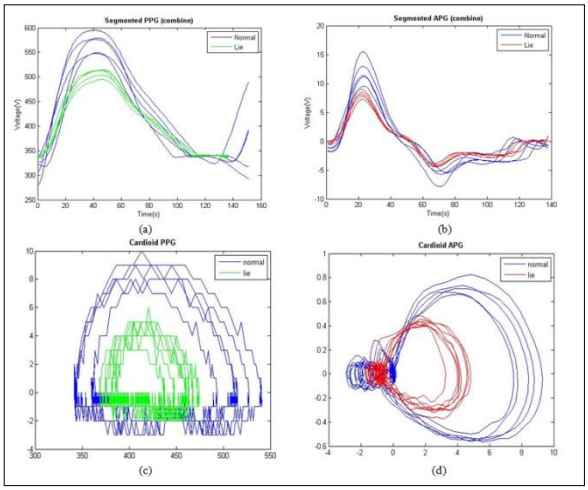

Figure 4: (a) Combined segmented PPG of Subject 1; (b) Combined segmented APG of Subject 1; (c) Combined cardioid PPG of Subject 1; (d) Combined cardioid APG of Subject 1.

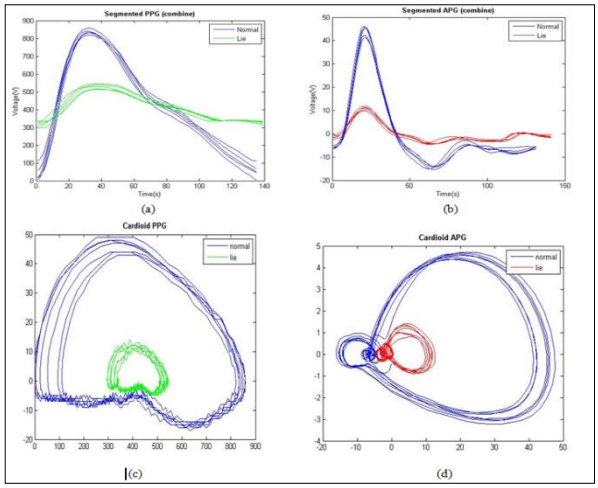

Figure 5: (a) Combined segmented PPG of Subject 6; (b) Combined segmented APG of Subject 6; (c) Combined cardioid PPG of Subject 6; (d) Combined cardioid APG of Subject 6.

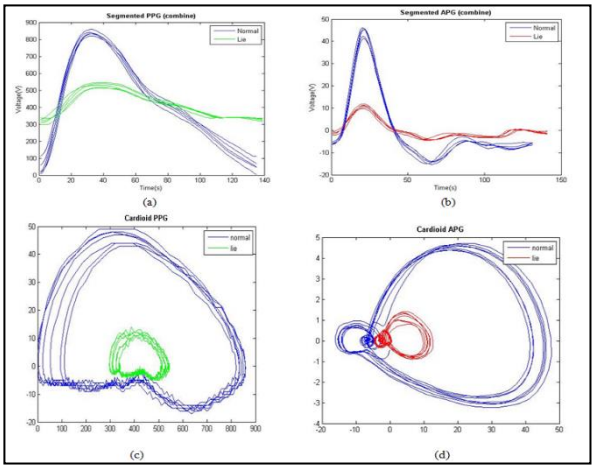

Figure 6: (a) Combined segmented PPG of Subject 9; (b) Combined segmented APG of Subject 9; (c) Combined cardioid PPG of Subject 9; (d) Combined cardioid APG of Subject 9.

Based on the outcome shown from Figures 4 until 6, it can be deduced that the pattern of PPG and APG signals are different since APG signal is the second derivative of the waveform of the digital PPG. APG signals separate components of the waveform to produce a clearer morphology than the first derivative. It has been labelled as a potential diagnostic tool for many medical problems and also disorders. It is also suitable to be used as an indicator of a lie detector since it gives much more information as compared to PPG signal. From the result, it can be clearly seen that the PPG and APG waveforms of an individual is different from one another. Since the analysis of this study is done by observing the criteria of the signals which includes measuring the average peak to peak distance, the average height distances between the segmented signals and the area of cardioid formed, Tables 4.1 until 4.3 concludes the findings of this study.

Table 1
Peak to Peak Interval analysis

Subject	PPI of PPG (N)	PPI of PPG (L)	PPI of APG (N)	PPI of APG (L)
Subject 1	151.3	139.0	150.8	103.8
Subject 2	196.3	166.3	196.3	166.5
Subject 3	186.0	123.8	184.8	119.8
Subject 4	187.8	186.3	188.5	187.0
Subject 5	163.0	150.3	161.8	149.3
Subject 6	141.8	142.5	142.0	141.8
Subject 7	165.8	177.0	165.8	178.3
Subject 8	121.3	113.8	121.3	113.3
Subject 9	98.8	83.0	99.5	83.0
Subject 10	178.3	165.0	134.3	166.5

* N = Normal
* L = Lie

From Table 1, it can observed that there is a slight difference in PPI between normal and lie conditions where there is a reducing pattern for both PPG and APG in in most of the subjects. From the results obtained we can deduced that lie detection using PPI as a parameter is not suitable for both PPG and APG as there is no significant difference between lying and normal conditions.

Height difference of segmented normal and lie conditions of the subjects can be seen in Figure 4 until Figure 6 from the combined 10 segmented signals of lie and normal signals for each respondent. From these figures, the distinction between the signals of the subject when they are in normal condition and when they are lying can be clerly seen. The peak or the a

point for both PPG and APG waves for all of the subjects appear to be lower when they are lying compared to their normal PPG and APG reading. To further prove that the reading between normal and lie peak points of signals are different, the average height difference between lie and normal condition are measured and tabulated in Table 2.

Table 2
Height difference analysis

Subject	Height difference PPG (Normal-Lie)	Height difference APG (Normal-Lie)
Subject 1	61.2	4
Subject 2	104.2	6.7
Subject 3	64.2	4.1
Subject 4	209.4	17.1
Subject 5	56.2	2.4
Subject 6	308.6	33.3
Subject 7	24.2	2.1
Subject 8	102.4	11.1
Subject 9	130.8	11.4
Subject 10	23.4	2.5

* N = Normal
* L = Lie

The Cardioid graph of PPG and APG and its variation between normal and deceptive states of the subjects can be observed in Figures 4 until 6. It is obvious that the area of Cardioid for both PPG and APG signals when the respondents are in normal conditions in bigger than when they are lying. The calculated average areas of Cardioid for both PPG and APG waveforms are recorded in Table 3 and it is proven that the area of Cardioid for both PPG and APG waveforms are smaller in lying state as compared to when the subjects are in normal condition for all of the subjects. The APG readings of all respondent recorded a relatively smaller reading as compared to PPG.

Table 3
Area of Cardioid analysis

Subject	Cardioid area PPG (N)(mV)	Cardioid area PPG (L)(mV)	Cardioid area APG (N)(mV)	Cardioid area APG (L)(mV)
Subject 1	20846.0	11068	141.2	72.1
Subject 2	96478.0	73263.0	687.7	549.3
Subject 3	7039.0	2819.0	44.4	22.4
Subject 4	102302.0	28175.0	759.7	203.8
Subject 5	9537.5	4106.0	54.3	29.5
Subject 6	238609.0	17615.0	2091.8	150.3
Subject 7	3231.0	994.0	20.1	6.9
Subject 8	207539.0	149110.0	2050.8	1653.6
Subject 9	48100.0	3646.5	499.6	43.5
Subject 10	14238.0	9840.0	110.4	68.9

* N = Normal
* L = Lie

V. CONCLUSION

As a conclusion, this study discovered lie detection using acceleration plethysmography signal through the five steps of the proposed methodology. This study also conducted literature review to further studied different types of lie detection. The final outcomes indicate that PPI is not suitable as a mean to differentiate deception and truth as the difference between these two signals are trivial whether from observation or from the measured value. On the other hand, Peak Height Difference and Cardioid graph are more suitable to detect lies in both PPG and APG signals since there are significant different in PPG and APG waveforms when subject are telling lies as compared to telling the truth. In case of Peak height difference, the height of peaks when the subjects are lying is lower as compared to when they are in a normal condition. For Cardioid graph, the area of the graph is bigger when subjects are telling the truth in contrast to when they are lying.

The pattern of PPG and APG waveforms shows a smaller form when the Subjects are lying as compared to when they are in normal conditions. This is due to the increase of heart beat when they are lying. When the heart beat speeds up, then concentration of oxygen decreases due to the increase of haemoglobin which gives red colour to the blood and the haemoglobin will restrict the amount of infrared light that can pass through to the photo-detector in Easy Pulse. Since PPG is obtained by measuring the oxygen saturation in the blood, smaller detection of light will result in smaller reading of PPG and APG indirectly.

ACKNOWLEDGEMENT

We would like to acknowledge International Islamic University Malaysia for providing us the Research Initiative Grant Scheme to fund this research.

REFERENCES

[1] Sensors, “On Time Domain Analysis of Photoplethysmogram Signals for Monitoring Heat Stress”, Accessed on 13 March 2016, http://www.mdpi.com/1424-8220/15/10/24716/htm

[2] Owayjan M.; Kashour A.; Al Haddad N.; Fadel M.; Al Souki G., “The Design and Development of a Lie Detection System using Facial Micro-Expressions”, 2012 2nd International Conference on Advances in Computational Tools for Engineering Applications (ACTEA) on pp. 1, 4, 5, 2012

[3] Singh B.; Rajiv P.; Chandra M., “Lie Detection Using Image Processing”, 2015 International Conference on Advanced Computing and Communication Systems (ICACCS -2015) on pp. 1-5, Jan. 05 – 07, 2015

[4] Lange D. H. and Inbar G. F., “Brain Wave Based Polygraphy”, pp. 1-3, Technion City, Haifa, Israel, 1996

[5] Noje D. I. and Malutan R., “Head movement analysis in lie detection”, Cluj-Napoca, Romania on pp. 1-4, 2015

[6] Zhu Z.; Tsiamyrtzis P.; Pavlidis I., “Forehead Thermal Signature Extraction in Lie Detection”, Proceedings of the 29th Annual International Conference of the IEEE EMBS Cité Internationale, Lyon, France on pp. 1-4, August 23-26, 2007

[7] Proudfoot J. G.; Jenkins J. L.; Burgoon J. K.; Nunamaker J. F., “Deception is in the Eye of the Communicator: Investigating pupil diameter variations in automated deception detection interviews”, 2015 IEEE on pp. 1-6, 2015.